The MINERνA neutrino scattering experiment

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for the

MINERνA collaboration
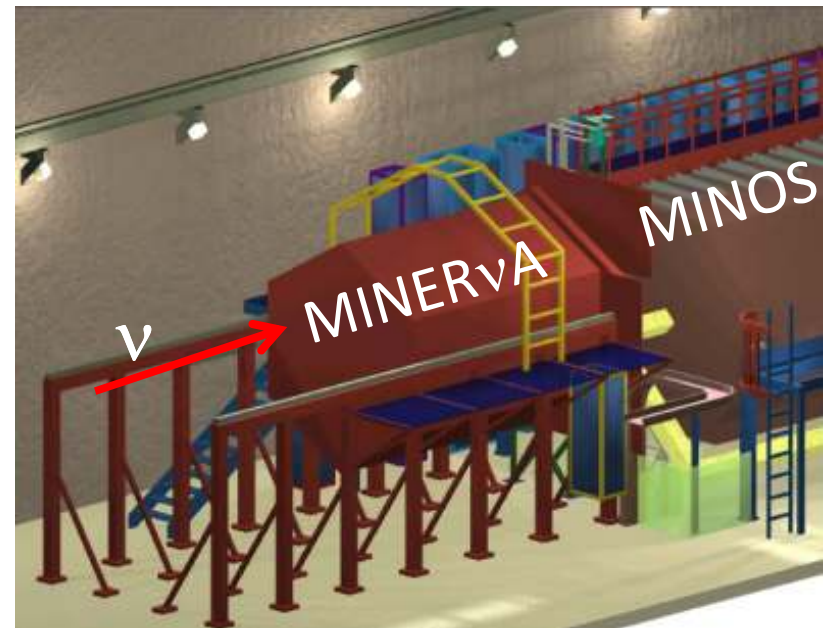
Motivation for MINERνA

- Small neutrino cross sections requires massive detector, heavy targets

- Heavy targets lead to nuclear effects:
  - Interaction probability on bound nucleons is different from free nucleons
  - Interaction of final-state particles with the nuclear medium further complicates the identification of ν reactions and distorting the particle energies
  - ➔ Requires understanding of nuclear effects on ν cross sections

- Inconsistent experimental results from recent ν cross section measurements
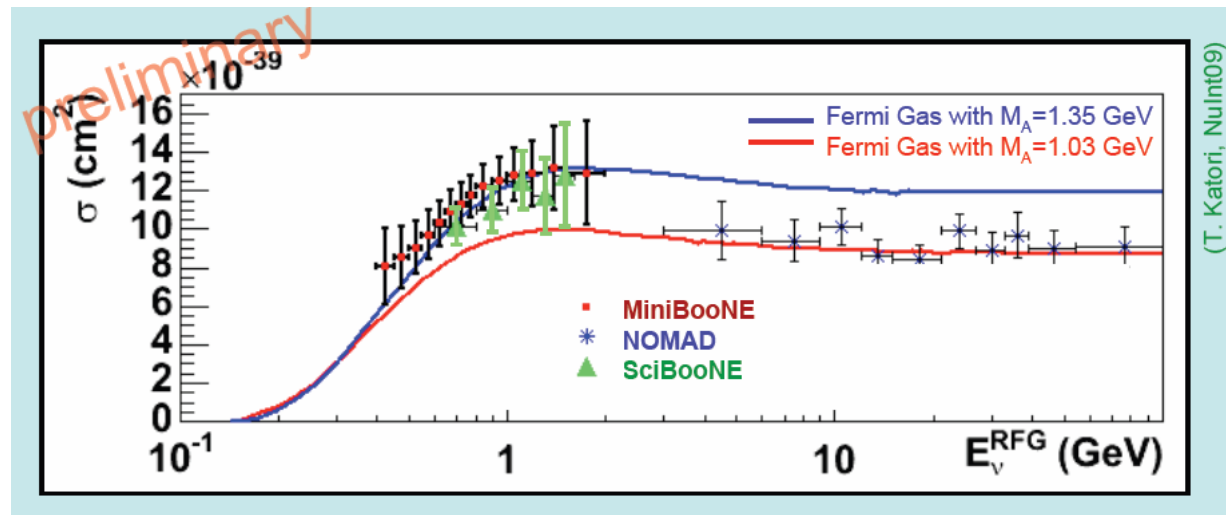
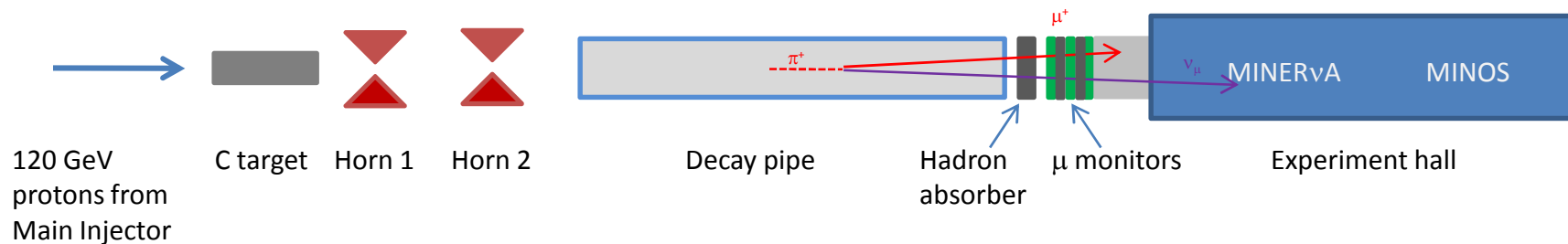# What is the MINERνA experiment?

- Neutrino scattering experiment at FNAL

- Intense neutrino beam from NuMI

- Several nuclear targets

- Fully active calorimeter with good tracking capability

- MINOS near detector as spectrometer

- High statistics

- Physics:
  - ➤ Precision cross section measurement
  - ➤ A-dependence of ν interactions
  - ➤ Precision measurement of axial form factor
  - ➤ Study of nuclear effects with ν interactions
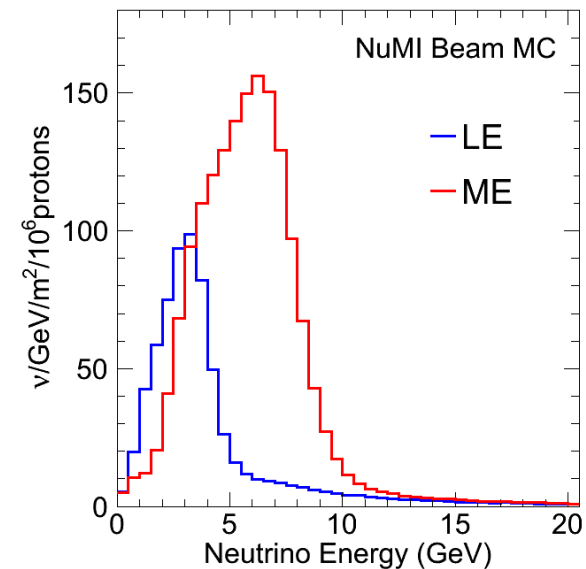
The ν beam and flux measurement

- Neutrinos are produced from the NuMI beamline

120 GeV protons from Main Injector   C target   Horn 1   Horn 2   Decay pipe   Hadron absorber   μ monitors   Experiment hall

- Flux can be measured using muon monitors
  - ✓ Measure the flux of muons which are produced together with ν from K, π decays
  - ✓ Different muon monitors `see` muons with different energy thresholds
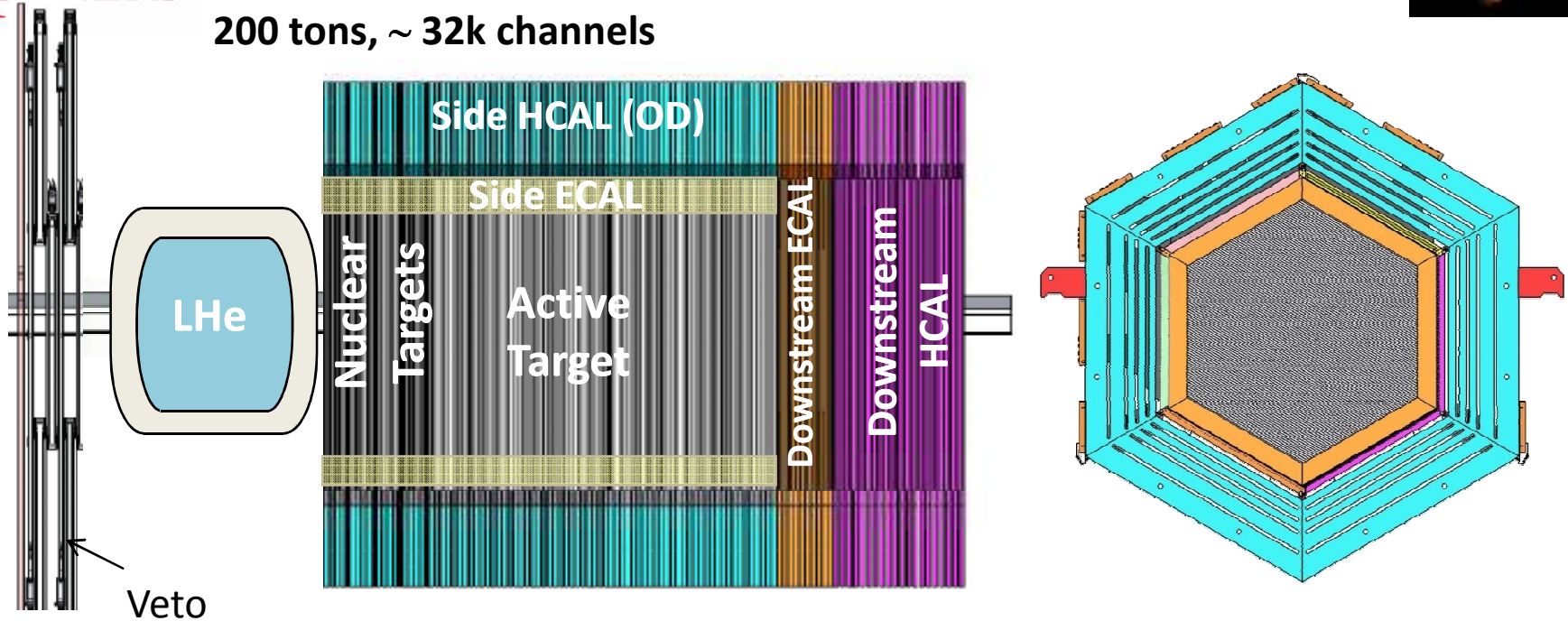- Goal is to understand flux shape and normalization to 10%
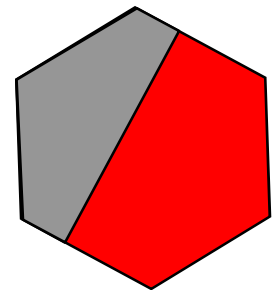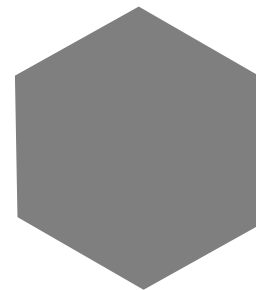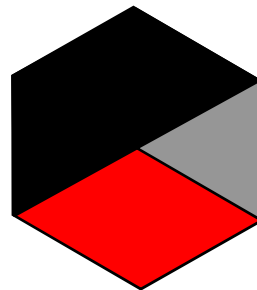

Neutrino spectrum

MINERνA Detector

200 tons, ~ 32k channels

Side HCAL (OD)

Side ECAL

Nuclear Targets

Active Target

Downstream ECAL

Downstream HCAL

LHe
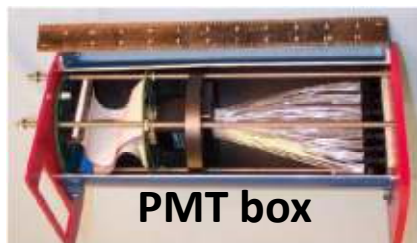
Veto

Nuclear targets: Fe (900 kg), Pb (900 kg) , C (150 kg), and H2O (not shown)
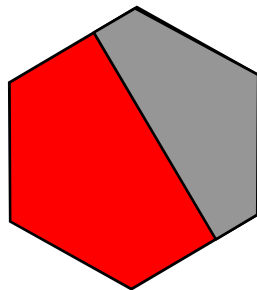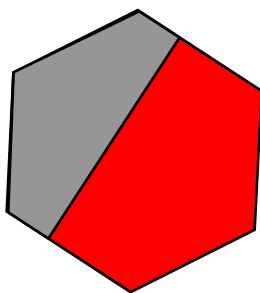
Detector channel
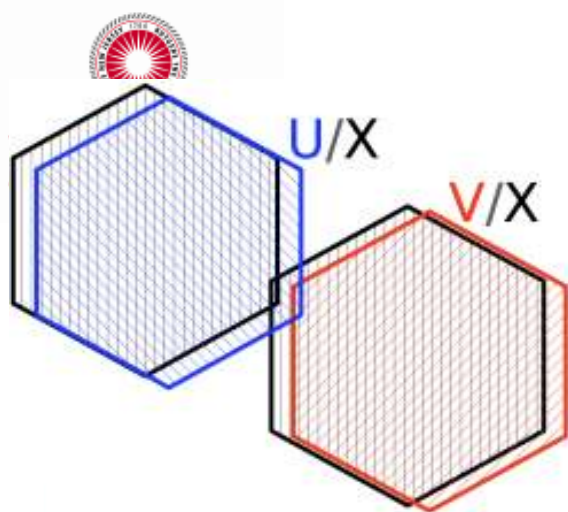
Hamamatsu M64

PMT box

Clear fiber

Plastic scintillator

WLS

1.7 cm

3.3 cm

U/X

V/X
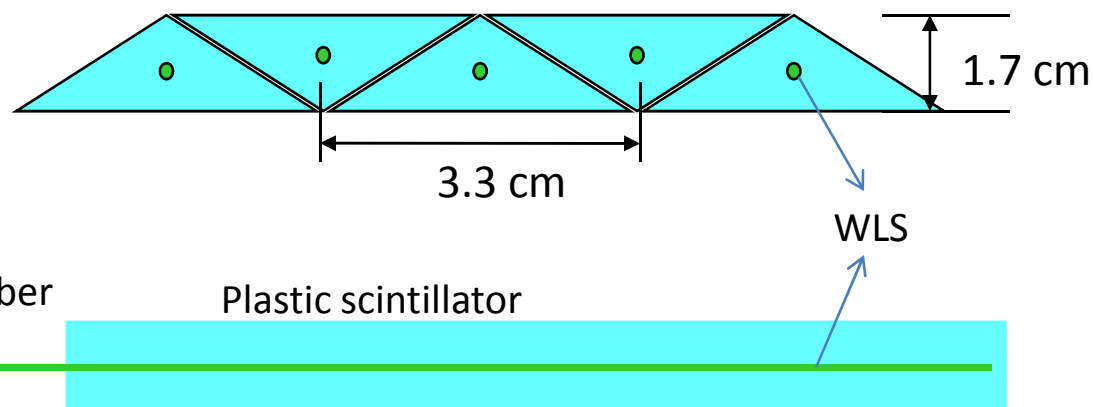
- ➢ Front-End-Board is mounted on top of the PMT box
  - ✓ 6 TriP-Ts, developed for D0
  - ✓ Read out 64 channels
  - ✓ Provide high voltage for the PMT
- ➢ FEBs are read out by Chain Readout Controller
  - ✓ VME-based module
  - ✓ Synchronize timing with MINOS and accelerator
  - ✓ Gate opens for 16 μs, every 2.2s

Estimated MINERνA <u>produced</u> event rates

Using the NUGEN Neutrino Event Generator

Assume 4.0×10^{20} **POT in LE and** 12.0×10^{20} **POT in the ME NuMI beam configurations**

Fiducial Volume = 3 tons CH, 0.25t He, 0.15t C, .35t H_2O, 0.9t Fe and 0.9t Pb
Expected CC event samples:
9.0 M ν events in CH
<u>0.6 M ν events in He</u>
<u>0.4 M ν events in C</u>
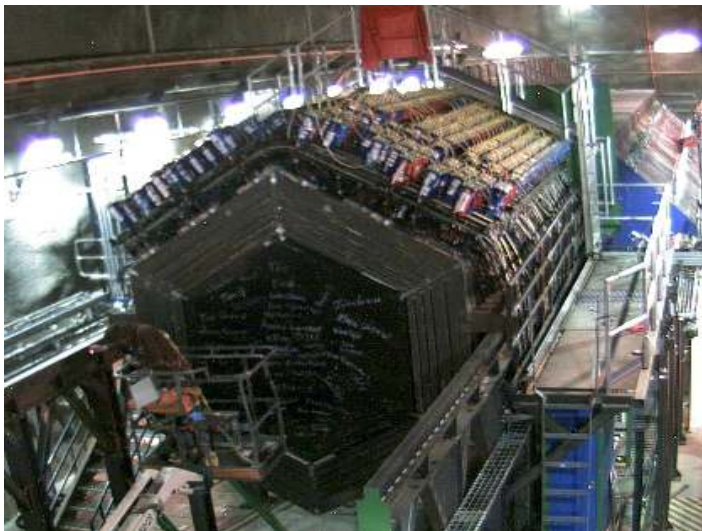<u>1.0 M events in H_2O</u>
<u>2.7 M ν events in Fe</u>
<u>2.7 M ν events in Pb</u>

MINERνA is taking data!

- Downstream 55% of the detector installed Nov. 2009, took anti-neutrino data until March 2010, 4×10^{19} POT

- Detector completed March 2010, started taking neutrino data

- Expected exposure:
  - Low-energy ($<E_\nu>$ = 4.0 GeV) neutrino, 4×10^{20} POT
  - Medium-energy ($< E_\nu >$ = 8.0 GeV) neutrino in NOνA era, 12×10^{20} POT

MINERνA in the experiment hall

Occupancy plot

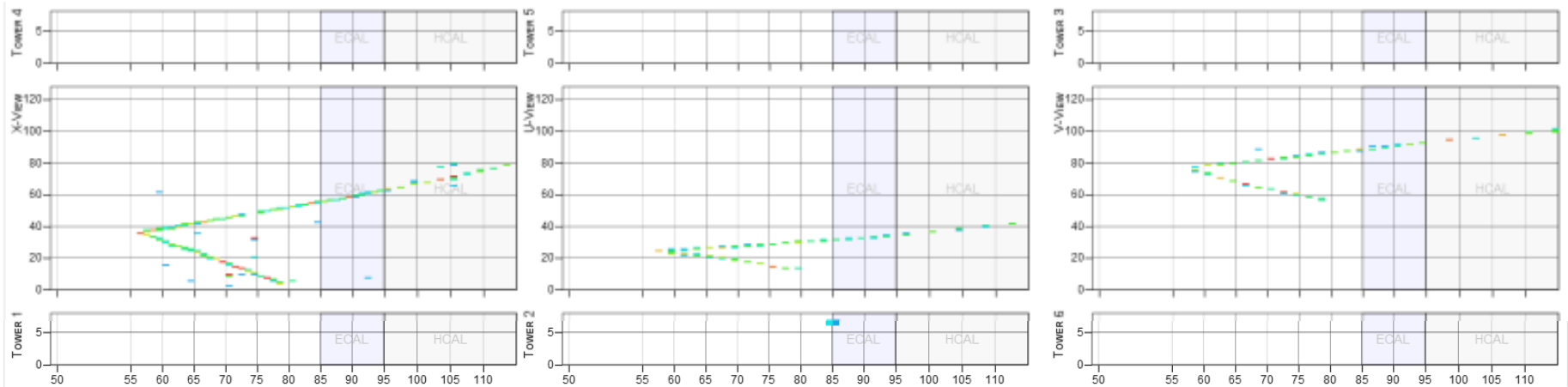Module Number (Discriminator FIRED)
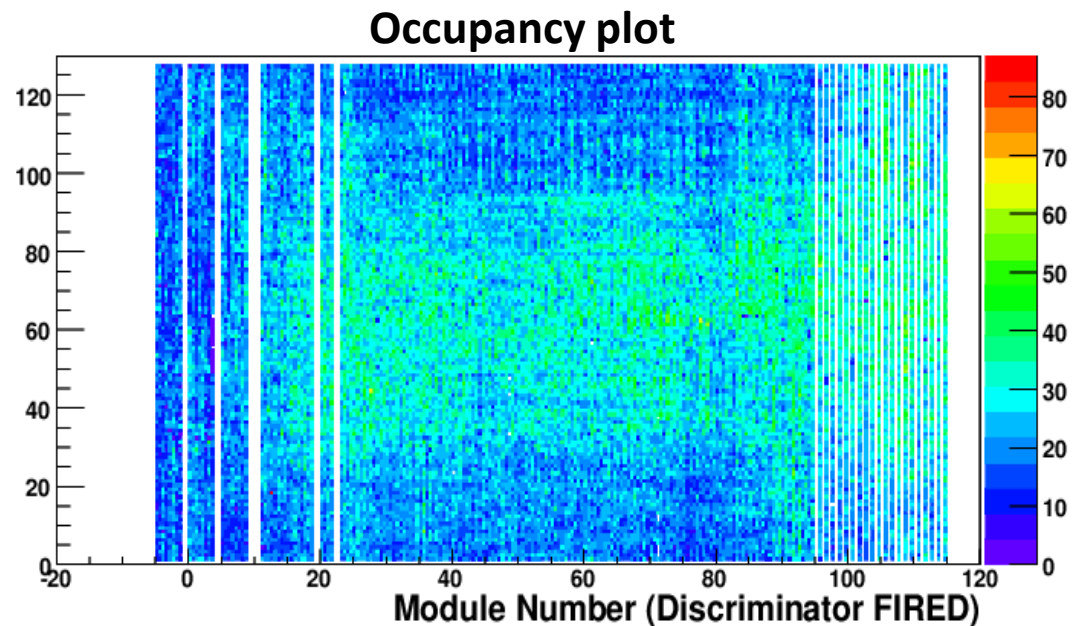
Event display

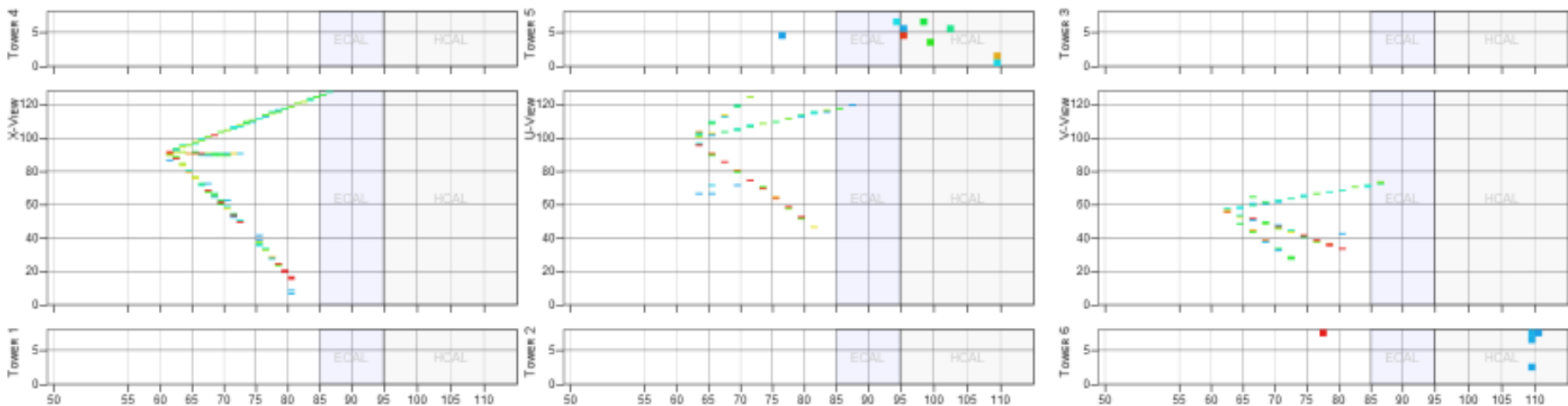Actual events from data

Event 1

Event 2

X view   U view   V view

10/28/2010   DNP Nov 4, 2010

Simulation & Event Reconstruction

- **MC simulation:**
  - ➢ Use GENIE as event generator
  - ➢ Use GEANT4 for particle transport

- **Event reconstruction:**
  - ➢ Hits from each readout gate are grouped into time slices using time
  - ➢ Each time slice is reconstructed independently
    - ➢ Charged particle tracks are detected in 2D using pattern recognition
    - ➢ Two-dimensional μ-like tracks from three views are matched to form 3D track
    - ➢ MINERνA tracks are matched to MINOS track for momentum and charge sign
    - ➢ Vertex fitting is done using 3D tracks
  - ➢ Particle identification using dEdx

- **Calibration:**
  - ➢ Correct for light attenuation in fibers
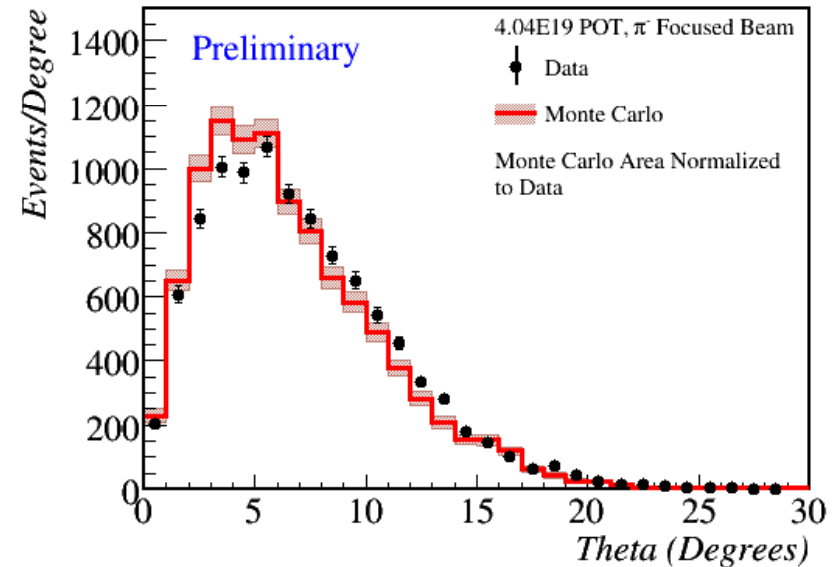 - ➢ Correct for channel response

Kinematic distribution

- Require MINOS matched track
- Reject rock muons
- Full-chain MC
  - Un-tuned flux
  - Area normalized to data
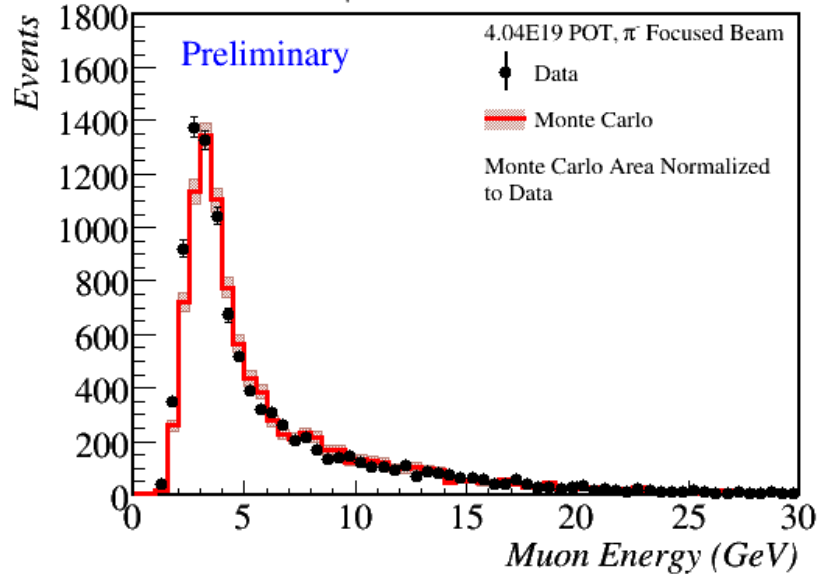
Kinematic distribution

Same as previous slide, but for ν_μ component in the $\overline{\nu}_\mu$ beam
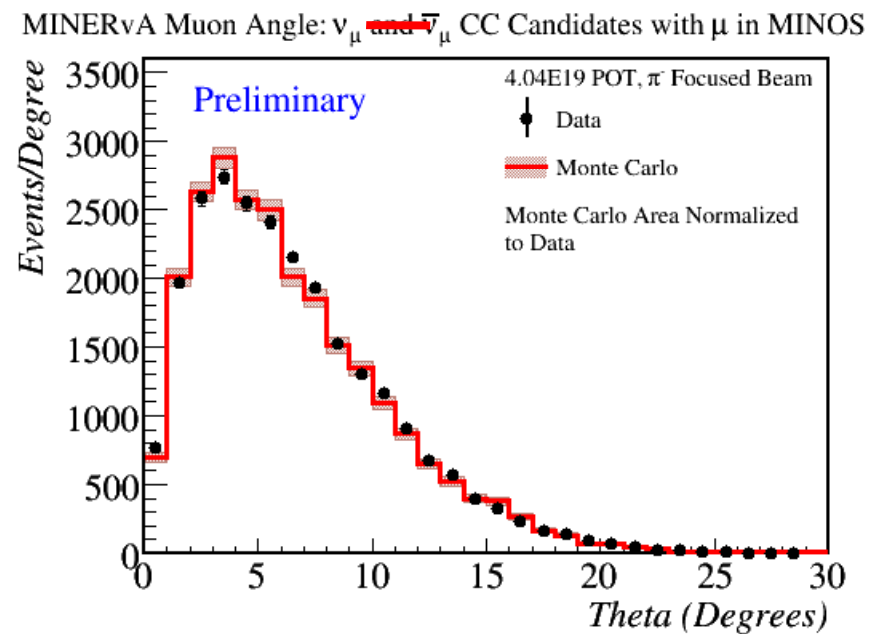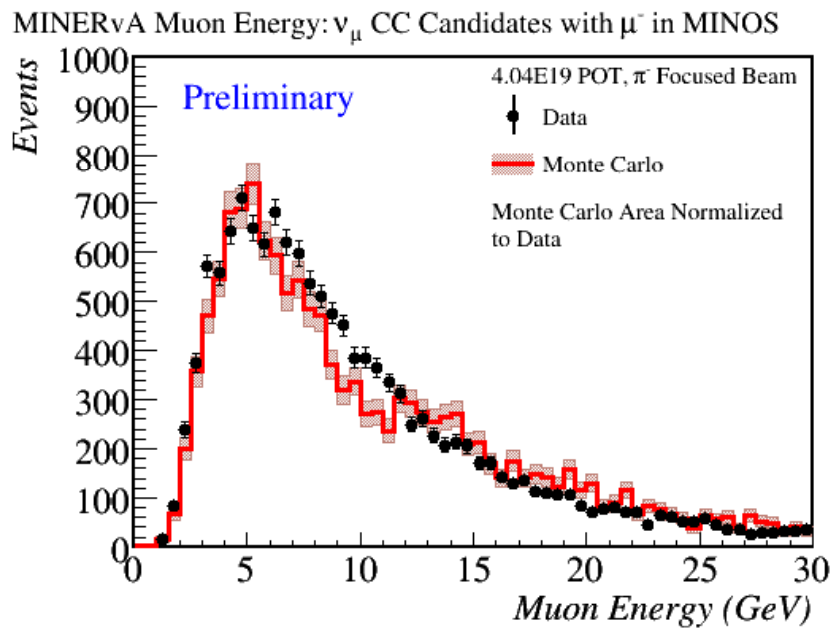
SUMMARY

- MINERνA is high statistics neutrino scattering experiment at FNAL using the NuMI beam

- Physics goals:
  - ✓ Precision cross section measurement
  - ✓ A-dependence of neutrino interactions
  - ✓ Precision measurement of axial form factor
  - ✓ Study of nuclear effects with ν interactions

- Taking data, data analysis tools being developed, preliminary results soon!